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SUMMARY REPORT

Pneumatic Impact Test

Evaluation of the Behavior of
Nonmetallic Materials in Hydrogen

MANNED SPACECRAFT CENTER
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LAS CRUCES, NEW MEXICO

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SUMMARY REPORT

Pneumatic Impact Tests

Evaluation of the Behavior of Nonmetallic Materials in Hydrogen

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1.0 INTRODUCTION

This test report is the fifth in a series of reports describing the results of tests conducted to evaluate the behavior of nonmetallic materials in hydrogen. This report summarizes the results of the pneumatic impact test (Test H) outlined in Test Plan TP-WSTF-196. The pneumatic impact test simulates the conditions resulting from the sudden release of high pressure on non-metallic materials within and outside pressure systems. The test is based upon MSC-PA-D-67-13 Test Number 10 which is designed to evaluate the reaction sensitivity of a material exposed to a pneumatic shock (step function) in oxygen systems. In this study performed for the NASA Aerospace Safety Reseach and Data Institute (ASRDI) and NASA WSTF, ten nonmetallic materials were evaluated to establish baseline data on the behavior of nonmetallic materials in hydrogen and to characterize, on an initial basis, one mode of material failure considered to be a factor pertinent to the safe use of a material in hydrogen.

2.0 SUMMARY

During May 1972, ten non-metallic materials were subjected to the pneumatic impact test. The tests were conducted following the procedure outlined in the Test Directive, TD-MIS-006, Revision B, using both GHe (baseline) and GH_2 as the test medium. None of the materials were significantly affected by the tests conducted using an impact pressure of 6,000 psia. Cellulose acetate butyrate, nylon, PRC polyurethane and polyethylene all exhibited surface melting as a result of the test. The samples of RTV-90 and polyvinyl chloride exhibited brown outer edges following the tests conducted in both test media. In addition the samples of polyvinyl chloride tested in GH_2 were colored a light green. In general the baseline tests conducted using helium produced a greater effect upon the samples than the tests conducted using hydrogen because of the higher temperature generated by the compression of helium.

3.0 TEST MATERIALS

3.1 Test Specimens: The following nonmetallic materials were examined by the pneumatic impact test:

WSTF Identification No.	Material
71-2992	FEP Teflon
71-3071	TFE Teflon
71-3072	15% Glass-Filled TFE Teflon
71-3073	High Density Polyethylene
71-2977	RTV-90 Silicone Rubber
72-3393	
71-3070	Viton-A
71-3074	Nylon 6
71-2978	PRC Polyurethane
71-3075	Polyvinyl Chloride
71-3198	Cellulose Acetate Butyrate

3.2 Test Gases: The test gases utilized in this series of tests conformed to the following requirements:

Gas	Requirements
Helium	MSFC Spec 364B
Nitrogen (purge gas)	MSFC Spec 234A
Hydrogen	High Purity Grade (99.0%)

4.0 TEST FIXTURE/SPECIMEN DESCRIPTION

A simplified schematic of the pneumatic impact test fixture is shown in figure 1. The carbon steel high pressure reservoir has an internal volume of approximately 0.35 cubic feet. The specimen cup and thermocouple assembly consists of stainless steel high pressure fittings. The thermocouple penetrates the end fitting and is located directly below the 0.188 inch diameter by 0.075 inch thick specimen. The high speed valve opens in approximately 2 milliseconds to provide the test chamber (containing the specimen) with high velocity test medium. This action raises the pressure on the test specimen to the test pressure in approximately 10 milliseconds. Figure 2 is a photograph of the actual test fixture utilized in this series of tests. Prior to testing each specimen is cleaned by soaking and agitiation (not ultrasonic) in a mild detergent solution for 5 minutes. The specimens are then rinsed thoroughly with deionized water and dried with filtered nitrogen and packaged in precleaned teflon bags until ready for testing.

5.0 GENERAL TEST PROCEDURE

The tests were conducted in duplicate using both GHe (baseline) and GH_2 as the test medium. The test procedure consisted of the following basic steps (refer to Appendix A for a detailed test procedure):

a. Place the specimen in the sample cup (refer to figure 1). Do not tighten the sample cup.

b. Purge the test fixture with GHe.

c. Tighten the sample cup connection.

d. Purge the test fixture with the test medium (either GHe or GH_2).

e. Isolate the high pressure reservoir.

f. Pressurize the high pressure reservoir to 6,000 PSIA with the test medium (GHe or GH_2).

g. Initiate high speed oscillograph data recording.

h. Subject the specimen to five pneumatic impact cycles consisting of the following sequence of events every twelve seconds.

T=0	open high speed valve
T+2 sec	close high speed valve
T+6 sec	open vent valve
T+11 sec	close vent valve

i. Terminate oscillograph data recording.

j. Vent high pressure reservoir to ambient pressure.

k. Purge test fixture with GHe.

l. Remove test specimen and examine for evidence of reaction (i.e. odor, discoloration, combustion, etc.)

6.0 TEST RESULTS

Figure three illustrates the data recorded during a typical test. The figure shows the sequenced operation of the high pressure isolation valve and the test specimen temperature and pressure during the test. The figure shows that the specimen temperature increases with each high pressure impact. Table I lists the initial and maximum temperature and maximum pressure data recorded on an oscillograph for each of the tests. Table I also lists the data from two baseline tests run without a specimen in the test fixture. The data from these tests indicates a temperature rise of approximately 30°F is obtained in either test medium. This small temperature rise is not a true indication of the temperatue exposed to the test specimen since the thermocouple is shielded and the test fixture surrounding the specimen area acts as a very large heat sink for the small quantity (less than 1.2 cubic inches) of hot gas. Dr. R.E. Bruce in a study of the gaseous oxygen pneumatic impact system (contract NAS 9-95390) stated that the gas temperature may be closely approximated by the following equation (isentropic compression):

$$T_f = T_o \left(\frac{P_f}{P_o} \right)^{\frac{\gamma-1}{\gamma}}$$

T_f = final gas temperature (°K)

T_o = initial gas temperature (°K)

P_f = final gas pressure (PSIA)

P_o = initial gas pressure (PSIA)

γ = ratio of specific heat at constant pressure to the specific heat at constant volume for each gas (H_2 = 1.4; He = 1.7)

Using the above equation the gas temperature at 6,000 PSIA should be approximately 2400°F using GH_2 and 5400°F using GHe as the test medium. The temperatures measured do however, reflect the relative temperature of the area adjacent to the test specimen and would adequately indicate the "burning" of a specimen if sufficient material were consumed in the reaction.

A review of the temperature data listed in Table I indicates that only one material, RTV-90, exhibited a large (greater than 20°F) temperature increase during the tests. Test numbers 31 and 38 performed using GH_2 on specimens of the RTV-90 prepared at WSTF (WSTF material identification number 71-2997) indicated temperature increases up to 29°F. These tests were conducted using RTV-90 that contained a considerable number of bubbles. In order to eliminate the effect of possible entrained or trapped gases, tests 44 through 47 were performed on RTV-90 purchased free from bubbles (WSTF material identification number 72-3393). Test numbers 44 through 46 subjected the RTV-90 to the standard sequence of five impacts while test number 47 subjected the material to 10 impacts. Only two of these four tests, numbers 54 and 47, indicated any appreciable temperature rise. In both cases the temperature rise was experienced toward the end of the impact sequence. Post test visual examination of the specimens from these two tests under low magnification (approximately 15X) showed the edges of the specimen from test number 47 were dark brown and light brown on the specimen from test number 45. This and other observations prompted visual examination of all the specimens under low magnification. Table II is a summary of the post test visual observations made on each test specimen. Several of the materials, cellulose acetate butyrate, nylon, PRC polyurethane and polyethylene exhibited bright melted surface with the specimens from the helium tests showing the greater change from the original (pre-test) condition. Figures four and five are photographs of the cellulose acetate butyrate and PRC polyurethane specimens. Each photograph clearly shows the differences among the original material and the specimens from the helium and hydrogen tests. The parallel marking on the specimens are a result of the formation process and are not a result of the test. Visual examination of the polyvinyl chloride specimen shown in figure six suggests that some surface reaction probably occured during the hydrogen tests as evidenced by the light green colored surface and the brown edges on the specimen. This condition was not observed on the specimens from the helium tests. The RTV-90 specimens also indicate the higher temperatures experienced during the helium tests by the dark brown edges on the specimens from tests 8 and 12. The intensity of the brown edges on this specimen subjected to 10 impacts in H_2 is similar to that observed on the specimens from the helium test.

A post test examination of the specimens for a change in hardness was also conducted following the general procedure outlined by ASTM D-1706. The results of the hardness tests are listed in Table III. As a consequence of the pneumatic impact specimen size the provisions of ASTM D-1706 relative to the size of the hardness specimen could not be met. The hardness data are therefore considered to reflect the relative hardness of the specimen and the original material. A review of the data listed in Table III indicates that only the hardness of the polyethlylene specimens was altered by the test conditions. The hardness of the polyethlylene specimens was reduced by approximately 20% on the specimens tested in both GHe and GH_2.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The pneumatic impact test indicated that none of the ten nonmetallic materials evaluated exhibited severe reactions at 6,000 PSIA impact pressure. Four of the materials, cellulose acetate butyrate, nylon, PRC polyurethane, and polyethylene, all exhibited surface melting as a result of the test. The baseline tests conducted using He produced a greater effect upon the samples than the tests conducted using H_2. The samples of RTV-90 also exhibited change as a result of the tests by the form of brown outer edges with the specimens from the helium tests showing the greater effect. The samples of polyvinyl chloride indicated a reaction occured in the hydrogen tests through the formation of a light green surface color change and the presence of brown edges on the specimens. In summary it is concluded that the tests conducted in helium were more severe than the tests conducted in hydrogen due to the higher temperature generated by rapid compression of the test media. It is also concluded that the materials examined satisfactorily passed the pneumatic impact test conducted as a parallel to the oxygen pneumatic impact test described by MSC-PA-D-67-13.

It is recommended that further pneumatic impact testing be conducted at higher pressures if warranted by potential use conditions. Because of the unanticipated but predictable test results obtained during the helium tests, consideration should be given to the occurance of pneumatic impact events within helium systems and its possible consequence.

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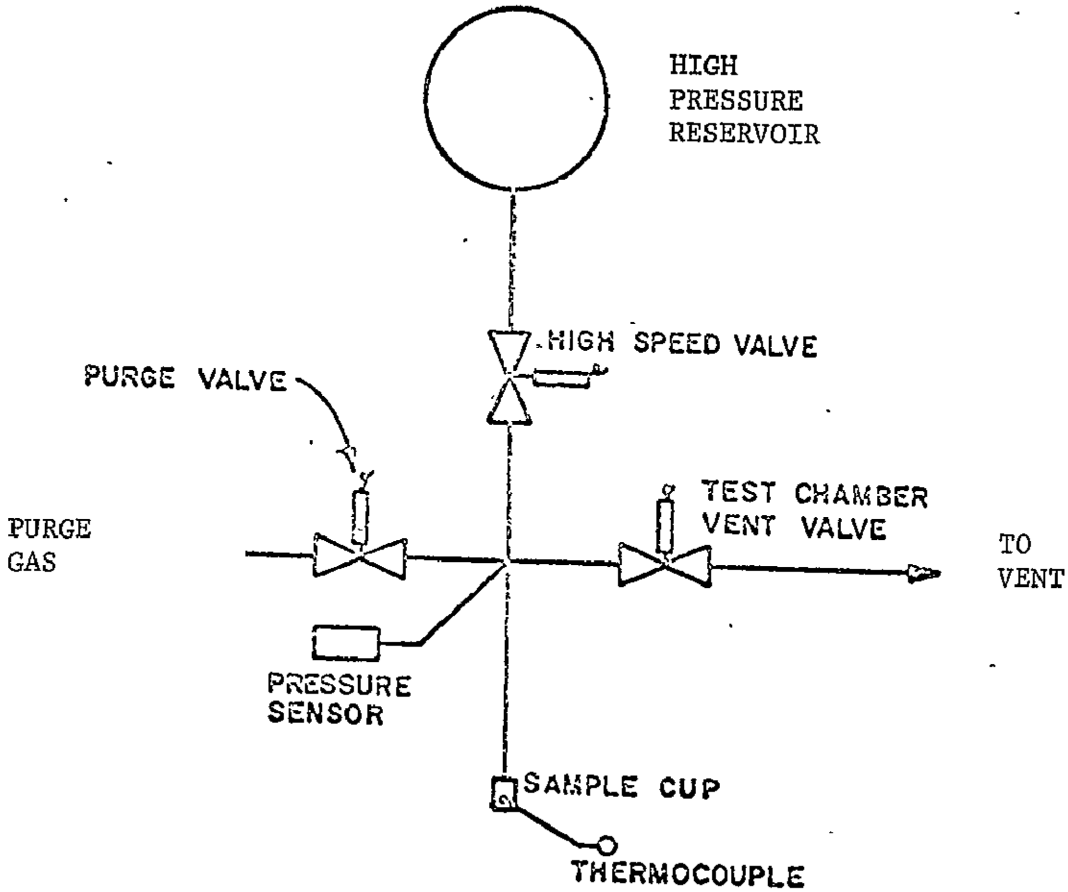

PNEUMATIC IMPACT TEST FIXTURE SCHEMATIC

FIGURE 1

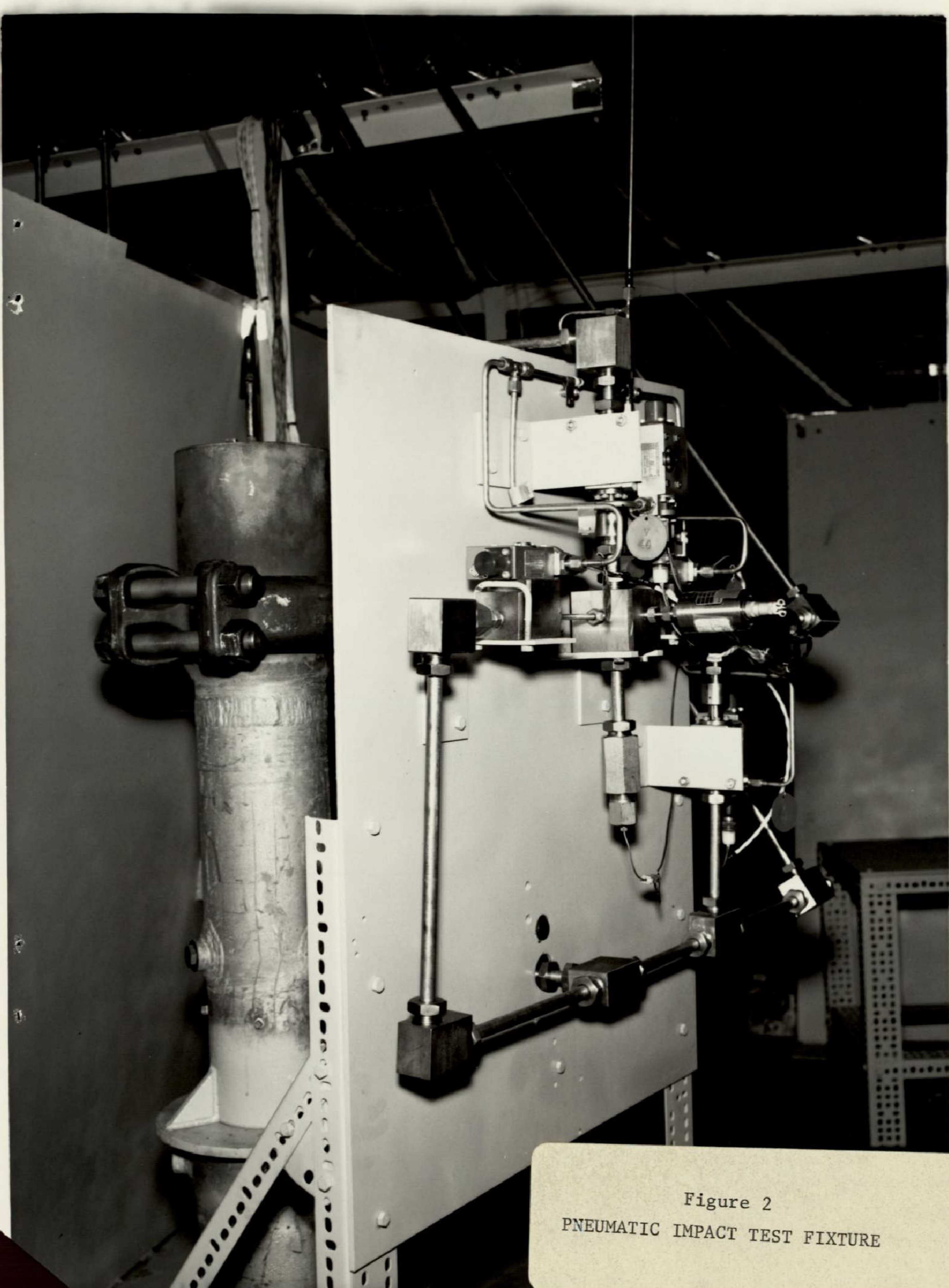

Figure 2
PNEUMATIC IMPACT TEST FIXTURE

NASA-WSTF
0572-0382

NASA-WSTF
0572-0432

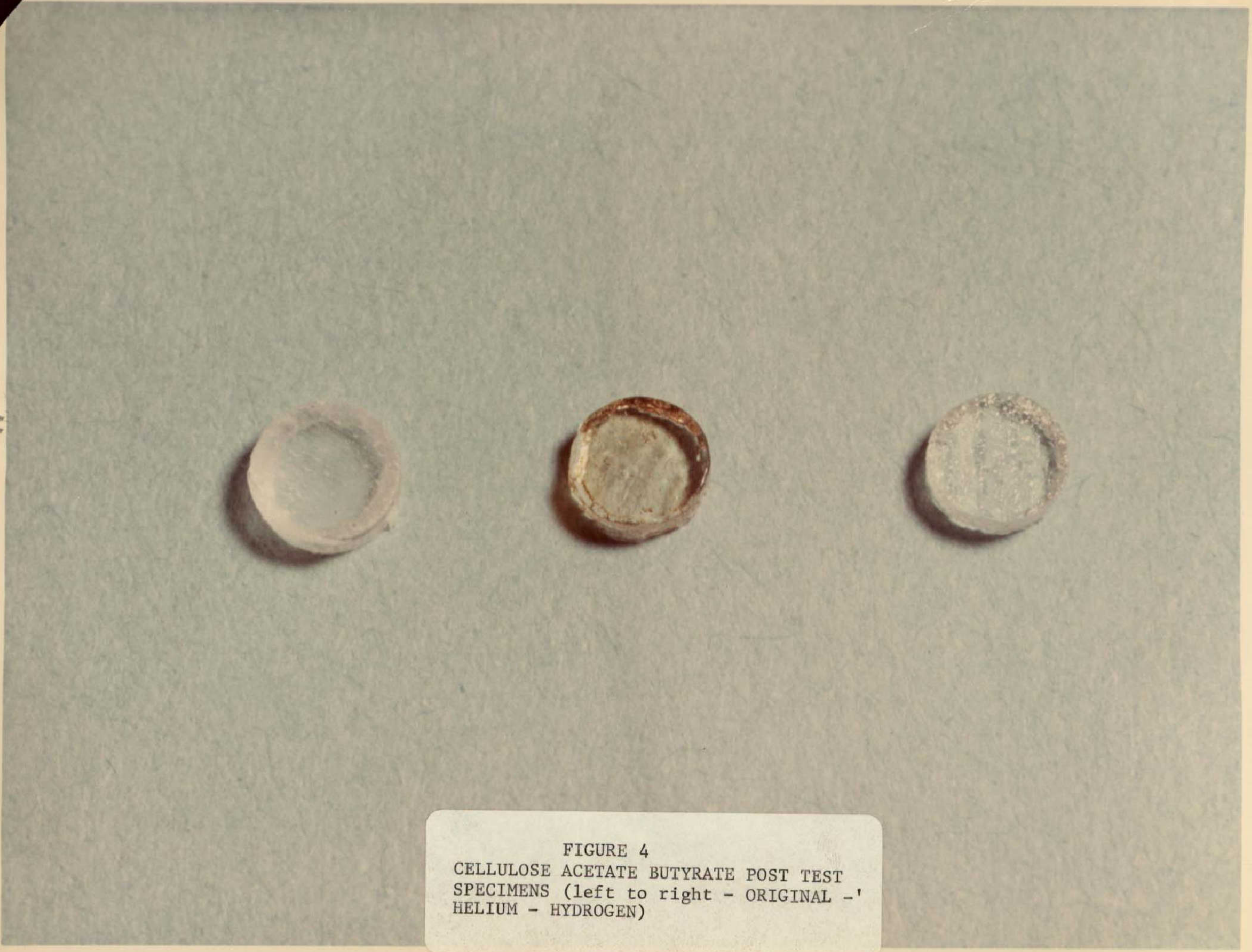

FIGURE 4
CELLULOSE ACETATE BUTYRATE POST TEST SPECIMENS (left to right - ORIGINAL - HELIUM - HYDROGEN)

NASA-WSTF
0572-0430

FIGURE 5
PRC POLYURETHANE POST TEST SPECIMENS
(left to right - ORIGINAL - HELIUM -
HYDROGEN)

NASA-WSTF
0572-0429

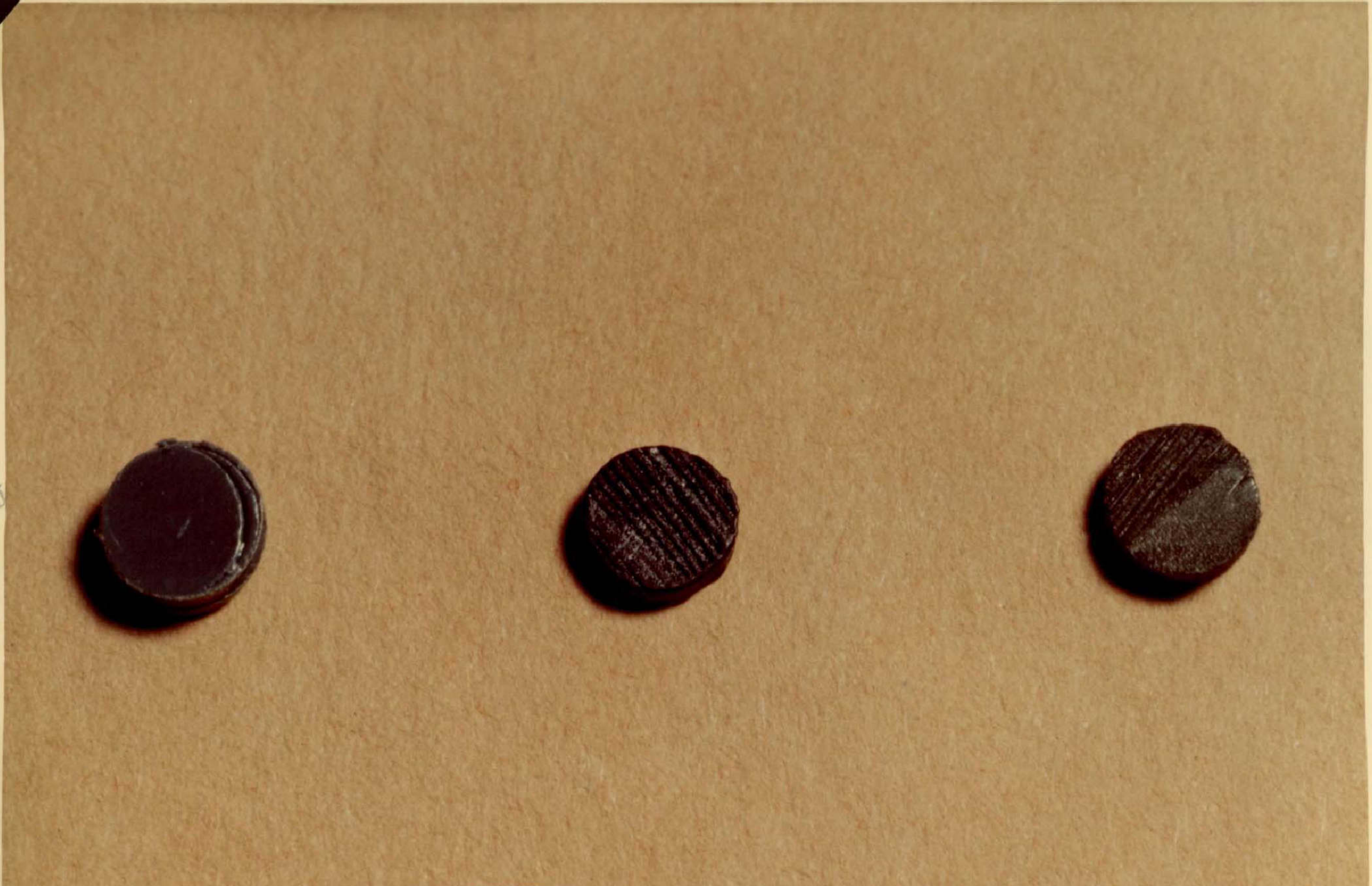

FIGURE 6
POLYVINYL CHLORIDE POST TEST SPECIMENS
(left to right - ORIGINAL - HELIUM - HYDROGEN)

Table I: Pneumatic Impact Test Data

Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
Empty test fixture							
	He	13	1	5980	65	104	39
			2	5930	74	104	30
			3	5860	74	109	35
			4	5860	74	109	35
			5	5830	82	109	27
	H_2	23	1	6000	76	100	24
			2	5900	80	104	24
			3	5900	80	109	29
			4	5900	80	113	33
			5	5860	84	113	29
Cellulose Acetate Butyrate (71-3198)							
	He	10	1	6030	67	78	11
			2	6030	74	82	8
			3	5980	74	82	8
			4	5930	74	82	8
			5	5930	78	84	6
	He	21	1	6000	82	86	4
			2	5960	82	88	6
			3	5930	82	88	6
			4	5930	82	88	6
			5	5860	88	94	6
	H_2	22	1	5980	76	84	8
			2	5900	80	84	4
			3	5880	80	84	4
			4	5880	80	88	8
			5	5830	84	88	4
	H_2	34	1	5980	78	82	4
			2	5980	78	86	8
			3	5930	82	86	4
			4	5880	82	90	8
			5	5830	86	90	4

Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
Nylon (71-3074)	He	3	1	6030	71	78	7
			2	6000	78	82	4
			3	5960	78	84	6
			4	5930	78	84	6
			5	5930	78	88	10
	He	19	1	6030	76	86	10
			2	5980	78	86	8
			3	5980	78	90	12
			4	5930	78	90	12
			5	5880	86	90	4
	H_2	29	1	6000	76	84	8
			2	5980	76	84	8
			3	5930	84	92	8
			4	5930	84	92	8
			5	5880	84	92	8
	H_2	42	1	5980	80	88	8
			2	5980	86	90	4
			3	5900	86	90	4
			4	5900	86	90	4
			5	5860	88	94	6
PRC Polyurethane (71-2978)	He	9	1	DATA LOST			
			2	6030	65	76	10
			3	5980	69	76	7
			4	5080	69	76	7
			5	5930	69	78	9
	He	16	1	6030	76	86	10
			2	6000	76	86	10
			3	5960	82	90	8
			4	5900	82	90	8
			5	5880	88	90	2
	H_2	24	1	5980	80	86	6
			2	5930	80	86	6
			3	5930	84	90	6
			4	5930	84	90	6
			5	5880	84	90	6

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Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
	H_2	35	1	6030	82	88	6
			2	5960	82	88	6
			3	5960	82	90	8
			4	5930	82	90	8
			5	5880	82	94	12
Polyethylene (71-3073)	He	7	1	6040	69	73	4
			2	6040	69	73	4
			3	6040	69	73	4
			4	5980	73	82	9
			5	5930	73	82	9
	He	17	1	5980	61	74	13
			2	5980	69	80	11
			3	5930	69	80	11
			4	5930	69	80	11
			5	5880	69	80	11
	H_2	30	1	6000	78	84	6
			2	5980	80	86	6
			3	5980	84	86	2
			4	5930	84	86	2
			5	5930	84	90	6
	H_2	40	1	6000	69	78	9
			2	5980	74	82	8
			3	5930	74	86	12
			4	5930	78	86	8
			5	5880	78	86	8
TFE Teflon (71-3071)	He	2	1	6030	69	78	9
			2	6030	74	78	4
			3	5960	74	78	4
			4	5960	74	84	10
			5	5960	78	84	6
	He	20	1	6000	76	84	8
			2	6000	80	84	4
			3	5960	84	88	4
			4	5900	84	92	8
			5	5860	88	92	4

Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
	H_2	27	1	6060	71	80	9
			2	6000	71	82	11
			3	5960	78	86	8
			4	5930	78	90	12
			5	5900	78	90	12
	H_2	33	1	5980	74	76	2
			2	5930	74	76	2
			3	5930	76	82	6
			4	5880	76	82	6
			5	5880	76	86	10
Polyvinyl chloride (71-3075)	He	1	1	6080	71	80	9
			2	5980	71	82	9
			3	5930	74	82	8
			4	5930	78	86	8
			5	5900	76	86	10
	He	18	1	6060	67	78	11
			2	6000	71	84	13
			3	6000	71	84	13
			4	5930	73	84	11
			5	5930	78	88	10
	H_2	26	1	6000	65	74	9
			2	5960	69	74	5
			3	5930	71	78	7
			4	5880	80	82	2
			5	5860	80	82	2
	H_2	36	1	5980	82	86	4
			2	5980	82	86	4
			3	5930	82	92	10
			4	5900	86	96	10
			5	5960	86	96	10
Viton-A (71-3070)	He	6	1	6080	69	80	11
			2	6040	69	80	11
			3	6040	69	80	11
			4	5950	73	86	13
			5	5950	73	86	13

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Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
	He	14	1	6000	74	84	10
			2	5960	80	84	4
			3	5900	80	88	8
			4	5900	80	88	8
			5	5900	80	88	8
	H_2	25	1	5980	65	74	9
			2	5930	65	74	9
			3	5930	69	80	11
			4	5880	69	80	11
			5	5860	74	80	6
	H_2	37	1	6030	82	90	8
			2	6030	82	90	8
			3	5960	82	90	8
			4	5900	82	90	8
			5	5900	82	92	10
FEP Teflon (71-2992)	He	5	1	6000	65	80	15
			2	No data	65	80	15
			3	No data	69	78	9
			4	No data	69	78	9
			5	No data	69	78	9
	He	11	1	6080	69	80	11
			2	6030	69	82	13
			3	5980	76	82	6
			4	5980	76	90	14
			5	5900	76	94	18
	H_2	32	1	5960*	65	76	11
			2	5320	65	76	11
			3	3750	69	76	7
			4	3290	69	76	7
			5	2940	69	76	7
			*Pressure leaked during test				
	H_2	39	1	6000	80	86	6
			2	5980	80	86	6
			3	5930	82	88	6
			4	5860	82	88	6
			5	5860	82	88	6

Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
	H_2	43	1	6000	82	94	12
			2	6000	88	96	8
			3	5960	88	96	8
			4	5900	88	96	8
			5	5860	88	100	12
15% Glass filled TFE Teflon (71-3072)	He	4	1	6040	96	104	8
			2	5920	96	104	8
			3	5920	96	104	8
			4	5920	102	111	9
			5	5820	102	111	9
	He	15	1	5980	78	90	12
			2	5960	78	94	16
			3	5900	82	94	12
			4	5880	90	94	4
			5	5830	90	94	4
	H_2	28	1	5980	74	84	10
			2	5930	74	86	12
			3	5930	78	88	10
			4	5880	78	90	12
			5	5880	84	94	10
	H_2	41	1	6000	84	94	10
			2	5960	84	94	10
			3	5930	84	94	10
			4	5930	86	94	10
			5	5860	86	98	12
RTV-90	He	8	No data	No data	No data	No data	No data
(71-2977)	He	12	1	5980	65	76	11
			2	5930	69	80	11
			3	5880	69	80	11
			4	5880	65	82	17
			5	5830	74	82	8
	H_2	31	1	6030	78	88	10
			2	5980	82	88	6
			3	5980	82	111	29
			4	5930	88	115	27
			5	5880	82	111	29

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Material	Media	Test No.	Impact No.	Maximum Impact Pressure (PSIA)	Initial Temp. (^oF)	Maximum Temp. (^oF)	ΔT (Max. - initial) (^oF)
	H_2	38	1	6060	69	74	5
			2	6000	69	80	11
			3	5980	74	98	24
			4	5930	74	98	24
			5	5930	74	98	24
RTV-90 (72-3393)	H_2	44	1	6000	84	90	6
			2	5930	84	98	14
			3	5930	90	102	12
			4	5900	90	102	12
			5	5860	90	102	12
	H_2	45	1	5980	84	94	10
			2	5960	84	102	18
			3	5930	84	102	18
			4	5930	84	115	31
			5	5880	84	115	31
	H_2	46	1	6000	69	80	11
			2	5980	69	80	11
			3	5960	74	82	8
			4	5930	74	82	8
			5	5880	74	86	12
	H_2	47	1	6000	74	84	10
			2	5960	74	84	10
			3	5960	78	84	6
			4	5900	78	90	12
			5	5860	78	96	18
			6	5860	82	100	18
			7	5830	86	113	27
			8	5800	86	107	21
			9	5800	86	107	21
			10	5730	86	107	21

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Table II: Post Test Visual Appearance of Test Specimen

Material	Media	Test No.	Post Test Visual Appearance of specimen compared to orginal condition (15X magnification)
Cellulose Butyrate (71-3198)	He	10	Melted surface-brown spots
	He	21	Melted surface-brown spots
	H_2	22	Melted surface
	H_2	34	Melted surface
Nylon (71-3074)	He	3	Melted edges
	He	19	Melted edges
	H_2	29	Bright melted edges
	H_2	42	Bright melted edges
PRC Polyurethane (71-2978)	He	9	Specimen light yellow-bright melted surface
	He	16	Specimen light yellow-bright melted surface
	H_2	24	Specimen light yellow-bright melted surface
	H_2	35	Specimen light yellow-bright melted surface
Polyethylene (71-3073)	He	7	Bright surface
	He	17	Bright surface
	H_2	30	Dull surface
	H_2	40	Dull surface
TFE Teflon (71-3071)	He	2	No change from pre-test conditions
	H_2	27	No change from pre-test conditions
	H_2	33	No change from pre-test conditions
Polyvinyl chloride (71-3075)	He	1	Bright surface
	He	18	Bright surface
	H_2	26	Surface green colored with brown edges
	H_2	36	Surface green colored with brown edges
Viton-A (71-3070)	He	6	No change from pre-test conditions
	He	14	No change from pre-test conditions

Material	Media	Test No.	Post Test Visual Appearance of Specimen compared to original condition (15X magnification)
	H_2	25	No change from pre-test conditions
	H_2	37	No change from pre-test conditions
FEP Teflon	He	5	No change from pre-test conditions
(71-2992)	He	11	No change from pre-test conditions
	H_2	32	No change from pre-test conditions
	H_2	39	No change from pre-test conditions
	H_2	43	No change from pre-test conditions
15% Glass-filled			
TFE Teflon	He	4	No change from pre-test conditions
(71-3072)	He	15	No change from pre-test conditions
	H_2	28	No change from pre-test conditions
	H_2	41	No change from pre-test conditions
RTV-90 (71-2977)	He	8	Brown edges
	He	12	Brown edges
	H_2	31	Light brown edges
	H_2	38	Light brown edges
RTV-90 (72-3393)	H_2	44	Light brown edges
	H_2	45	Light brown edges
	H_2	46	Light brown edges
	H_2	47*	Dark brown edges

*Ten impacts

Table III: Post Test Hardness of Test Specimens

Material		Media	Test No.	Hardness - front and back of test specimen (Durameter D
Cellulose Acetate Butyrate			Baseline	78;78
		He	10	78;78
(71-3198)		He	21	79;75
		H_2	22	78;78
		H_2	34	77;80
Nylon			Baseline	82;81
(71-3074)		He	3	80;81
		He	19	81;81
		H_2	29	82;81
		H_2	42	81;81
PRC Polyurethane			Baseline	30;30
(71-2978)		He	9	34;32
		He	16	30;30
		H_2	24	30;26
		H_2	35	30;28
Polyethylene			Baseline	65;64
(71-3073)		He	7	55;55
		He	17	53;51

Material	Media	Test No.	Hardness - front and back of test specimen (Durameter D)
	He	30	56;56
	He	40	55;55
TFE Teflon		Baseline	53;55
(71-3071)	He	2	56;56
	He	20	53;53
	H_2	27	53;52
	H_2	33	51;54
Polyvinyl Chloride		Baseline	80;79
(71-3075)	He	1	79;80
	He	18	84;82
	H_2	26	80;80
	H_2	36	81;81
Viton-A		Baseline	38;39
(71-3070)	He	6	37;37
	He	14	37;37
	H_2	25	30;32
	H_2	37	35;35

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Material	Media	Test No.	Hardness - front and back of test specimen (Durameter D
FEP Teflon		Baseline	55;55
(71-2992)	He	5	54;57
	He	11	55;54
	H_2	32	57;57
	H_2	39	60;57
TFE Teflon		Baseline	52;51
15% Glass-filled	He	4	50;53
(71-3072)	He	15	52;51
	H_2	28	50;50
	H_2	41	50;50
RTV-90		Baseline	25;25
(71-2977)	He	8	27;29
	He	12	31;31
	H_2	31	30;30
	H_2	38	35;35
RTV-90		Baseline	25;25
(72-3393)			

Material	Media	Test No.	Hardness - front and back of test specimen (Durameter D)
	H_2	44	24;25
	H_2	45	24;26
	H_2	46	25;27
	H_2	47*	21;22

*Ten Impacts

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APPENDIX A

Daily Set-up and Shut-down

TEST PROCEDURE

Daily Set-Up and Shut-Down

TPS No. 3-HYD-044 (R)
TPS Short Title: Daily Set-Up and Shut-Down
Reasin for Work: To support 3-HYD testing

Item No.	Description
	DAILY SET-UP
1.	Open or verify open V-208 and verify 115±5 PSIG on G-35.
2.	Open or verify open MV-27.
3.	Open GV-247.
4.	Close or verify closed MV-6, MV-13, and MV-20.
5.	Power-up C14-602 console, bay 1 and bay 2.
6.	Verify arm key off.
7.	Verify following valve positions:
	Bay 1---------------------Valve and Main 455 ON
	Bay 2--------------------SV-1 Closed
	SV-2 Open
	SV-3 Open
	SV-8 Closed
	SV-9 Open
	SV-10 Open
	SV-15 Closed
	SV-16 Open
	SV-17 Open
	SV-23 Closed
	SV-25 Closed
	SV-36 Closed
	SV-44 Closed
	SV-45 Closed
	SV-46 Closed
	SV-47 Closed
	SV-48 Closed
	Spark generator off.
	Sequence off.
8.	Close SV-2, SV-9, and SV-16.
9.	Ensure PRV-254 is fully decreased.
10.	Slowly open V-256 and V-253.
11.	Open MV-207 and verify 25±5 PSIG on PI-256.
12.	Open SV-45 and SV-47.
13.	Open SV-2, SV-9 and SV-16.

Item No.	Description
14.	Pruge for approximately 1 minute.
15.	Close SV-2, SV-9, and SV-16.
16.	Open SV-23, and adjust PR-1 as required to obtain 100$\pm$10 PSIG on G-34.
17.	Open SV-1, SV-8, and SV-15.
18.	Purge for approximately 2 minutes, then close SV-1, SV-8 and SV-15.
19.	Close SV-23.
	(Note: Steps 20 thru 22 for hydrogen gas media only).
20.	Open MV-37, MV-39, and adjust PR-40 to obtain purge.
21.	Purge for 3 minutes, then close MV-39, PR-40, and MV-37.
22.	Open MV-264.

DAILY SHUT-DOWN

23.	Close MV-207. (Note: Perform steps 24 thru 26 for hydrogen testing).
24.	Open MV-253 and adjust PRV-254 as required to obtain 30$\pm$5 PSIG on PI-256.
25.	Open MV-39, MV-37, and adjust PR-40 to obtain purge.
26.	Purge for 5 minutes, then close MV-39, PR-40 and MV-37.
27.	Close GV-247 and GV-264.
28.	Close PRV-254.
29.	Verify or position the following valves.

SV-1	Closed
SV-2	Open
SV-3	Open
SV-8	Closed
SV-9	Open
SV-10	Open

SV-15	Closed
SV-16	Open
SV-17	Open
SV-23	Closed
SV-25	Closed
SV-36	Closed
SV-44	Closed
SV-45	Closed
SV-46	Closed
SV-47	Closed
SV-48	Closed

Spark generator off.
Sequence off.

30. Place TS-302 in a green condition.

31. Turn off main and valve 455 on Bay 1.

32. Power down C14-602, bay 1 and bay 2.

33. Change hydrogen and or helium K-bottle as required to support testing.

Perfrom Test H (Pneumatic Impact) Tests

TPS No. 3-HYD-100 (R)
TPS Short Title: Perform Test H (Penumatic Impact) Tests
Reason for work: To evaluate the behavior of materials subject to Pneumatic Impact.

Item No.	Description
1.	Verify daily set-up per TPS 3-HYD-044 (R) is complete.
2.	Verify camera (TV) set-up is complete and picture is able to TC.
	Install sample per steps three thru eight.
3.	Close SV-44, 45, and 47.
4.	Remove sample holder from the test chamber.
5.	Install sample, as designated on the log sheet, in the sample holder.
6.	Install sample holder in test chamber, and leave test chamber loosely attached.
7.	Open SV-47 and SV-9 and purge chamber for approximately 1 minute.
8.	Close SV-9 and tighten test chamber.
8a.	Connect sample thermocouple. (23T). Perfrom the following steps, 9 thru 18, to purge system when changing over to helium gas as the test media.
9.	Open SV-23, SV-8 and SV-10, and adjust PR-1 regulator to indicate 100±10 PSIG on G-34.
10.	Open SV-48.
11.	Close SV-44, SV-47, SV-46, and SV-45.
12.	Pressurize cylinder, then close SV-8.
13.	Open SV-46, vent cylinder, then close SV-46.
14.	Open SV-8.
15.	Repeat steps 12 thru 14 five times.

16. Open SV-44, and SV-45 and purge for approximately 1 minute.

17. Close SV-44 and SV-45.

18. Close SV-23.

Perform the following steps, 19 thru 22, to purge system when conducting repetative tests using helium gas as the test media.

19. Open SV-23 and SV-8 and adjust PR-1 regulator to indicate 100±10 PSIG on G-34.

20. Open SV-45 and SV-47 and purge for approximately 1 1/2 minutes.

21. Close SV-47.

22. Close SV-23.

Perform the following steps, 23 thru 37, to purge system when changing over to hydrogen gas as the test media.

23. Open H_2 "K" bottle outlet valves or source valve.

24. Adjust PR-40 for 100±20 PSIG as indicated on G-42.

25. Close building 328 area and make announcements.

26. Open building 328 and attach grounding straps.

27. Open SV-25, SV-8, and SV-10.

28. Open SV-48.

29. Close SV-44, SV-47, SV-46, and SV-45.

30. Pressurize cylinder, then close SV-8.

31. Open SV-46, vent cylinder, then close SV-46.

32. Open SV-8.

33. Repeat steps 30 thru 32 five times.

34. Open SV-44 and SV-45 and purge for approximately 1 minute.

35. Close SV-44 and SV-48.

36. Open SV-45 and SV-47, purge for approximately 1 ½ minutes.

37. Close SV-47 and SV-25.

Perform the following steps, 38 thru 44, to purge system when conducting repetative tests using hydrogen gas as the test media.

38. Open H_2 "K" bottle outlet valves or source valve.

39. Adjust PR-40 for 100±20 PSIG as indicated on G-42.

40. Close building 328, and make announcements.

41. Open building 328, and attach grounding straps.

42. Open SV-25, SV-8, and SV-10.

43. Open SV-45 and SV-47, purge for approximately 1 ½ minutes.

44. Close SV-47 and SV-25.

Pressurize cylinder using the following procedures:
steps 45 thru 50 when using He gas as test media;
steps 51 thru 57 when using H_2 gas as test media;

HELIUM TEST

45. Close MV-27, SV-44, SV-45, SV-46,and SV-47.

46. Open SV-8 and SV-48.

47. Close SV-25.

48. Open SV-23, and adjust PR-1 regulator to maximum outlet pressure indicated on G-34.

48a. Close building 328 and make announcements.

49. Cycle SV-36 as required to pressurize cylinder to 6,000±50 PSIA as indicated on 4P transducer.

50. Close SV-23 and SV-48.

HYDROGEN TEST

51. Close MV-27, SV-44, SV-46, and SV-47.

52. Open SV-8, and SV-10.

53. Close SV-23.

54. Adjust PR-40 for maximum outlet pressure as indicated on G-42.

55. Open SV-25.

56. Cycle SV-36 as required to pressuirze cylinder to 6,000±50 PSIA as indicated on 4P transducer.

57. Close SV-25 and SV-48.

Perform Pneumatic Impact test per steps 58 thru 60.

58. Open SV-10.

59. Close SV-44, SV-45, SV-46, SV-47, and Sv-48.

60. Cycle sequence on-sequence off per the following:

T-15 sec. Perform R-cal on oscillograph

T-6 sec. Turn on oscillograph

T+0 Depress sequence on

T+11.5 or at completion of SV-45 closed

Depress sequence off

T+12 Depress sequence on

T+23.5 or at completion of SV-45 closed

Depress sequence off

T+24 Depress sequence on

T+35.5 or at completion of SV-45 closed

Depress sequence off

T+36 Depress sequence on

T+47.5 or at completion of SV-45 closed.

Depress sequence off

T+48 Depress sequence on

T+59.5 or at completion of SV-45 closed

Depress sequence off

T+66 Turn off oscillograph

Perform R-cal on oscillograph

Purge system per the following steps:

61. If helium is test media, close PR-1.

62. Close SV-25 and SV-23.

63. Open SV-48 and SV-46.

64. Vent system to ambient, then close SV-48,SV-44, and SV-8.

64a. Open building 328 and make announcements.

65. Close H_2 "K" bottle or source valves, if applicable.

66. If H_2 is test media, close PR-40, open MV-37 and vent system, then close MV-37.

67. Open SV-45, SV-46, SV-47, and SV-9.

68. Purge for approximately 2 minutes, then close SV-46.

69. Purge for approximately 2 minutes, then close SV-47.

70. Vent system to ambient, then close SV-45 and SV-9.

71. Remove sample holder from test fixture.

72. Remove sample and deliver to TC.

73. Log sample results (visual examination).

74. Clean sample holder, if necessary, with a brush and Freon-TF.

At completion of hydrogen testing or at the test conductors direction, perform the following purge per steps 75 thru 90.

75. Close H_2 source valves and SV-25.

76. Install sample holder in fixture.

77. Close SV-44, SV-45, SV-46, and SV-47.

78. Open SV-23 and adjust PR-1 regulator for 100 ± 10 PSIG as indicated on G-34.

79. Open SV-8, SV-48, and SV-10.

80. Pressurize cylinder, then close SV-8.

81. Open SV-46, vent cylinder, then close SV-46.

82. Open SV-8.

83. Repeat steps 80 thru 82 ten times.

84. Open SV-44 and SV-45, and purge for approximately 2 minutes.

85. Close SV-44 and SV-48.

86. Open SV-47, purge for approximately 2 minutes.

87. Close SV-47.

88. Open SV-46, purge for approximately 2 minutes.

89. Close PR-1 regulator.

90. Vent system to ambient, then close SV-23 and SV-8.

Note: Steps 91, 92, to be performed at completion of daily testing.

91. Perform shut-down per TPS 3-HYD-044 (R).

92. Turn off TV camera and close building 328.